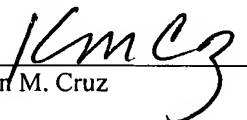BE IT KNOWN, that **Jesse Peter Keller** has invented a new and useful improvement in:

**SELF-CONTAINED, ON-BOARD, CAN-TO-FIELDBUS
CONVERTER AND METHOD OF USING THE SAME**

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SELF-CONTAINED, ON-BOARD, CAN-TO-FIELDBUS CONVERTER AND

METHOD OF USING THE SAME

FIELD OF THE INVENTION

5 [01] The field of the invention relates to systems and methods for use on heavy-duty surface vehicles to interface on-board computers and control area networks ("CANs") to industrial devices, components, and subsystems not specifically designed for use on vehicles.

10 ## BACKGROUND OF THE INVENTION

[02] Many modern heavy-duty vehicles include on-board computers interconnected with high-speed data links. The dashboard, engine, and transmission may each have a specialized computer, all sharing the same communications protocol. Because each device, component, and subsystem is

15 specifically built to function as part of an integrated vehicle system, all the control and status-reporting data communications interfaces are originally designed to be compatible with a vehicle CAN standard.

[03] Recently, there is a trend toward running high-powered accessories (e.g., air conditioning, steering, and braking) electrically using industrial automation

20 components not specifically designed for vehicle use.

[04] A problem with industrial automation components is that they do not communicate with the preexisting vehicle computer networks.

SUMMARY OF THE INVENTION

[05]   Accordingly, an aspect of the invention involves a method of communicating a message between an automotive device of an automotive

5   control area network and a non-automotive, industrial device of a non-automotive, fieldbus network. For the purposes of this invention, a fieldbus network is defined to be any data communications network specified by hardware and software protocols with formats native to the industrial device that are different from the protocols that specify the automotive control area network. The

10   method includes receiving a message of a native format from either one of the automotive devices of the automotive control area network or one of the non-automotive, industrial devices of the non-automotive, fieldbus network; translating the original native message format to a common language format; processing the message of a common language format via a set of stored,

15   configurable rules; translating the processed message of a common language format to the appropriate destination native message format; and delivering the message of destination native format to the desired automotive device or non-automotive, industrial device.

20   ## BRIEF DESCRIPTION OF THE DRAWINGS

[06]   The accompanying drawings, which are incorporated in and form a part of this specification, illustrate embodiments of the invention and together with the description, serve to explain the principles of this invention.

[07]   Figure 1 is a block diagram depicting an embodiment of a self-contained, on-board, CAN-to-fieldbus converter for accommodating the communication of industrial devices of a fieldbus network with automotive devices of a CAN of a vehicle.

5   [08]   Figure 2 is a diagram of the logical connection embodiment of a microprocessor and a database of the self-contained, on-board, CAN-to-fieldbus converter.

[09]   Figures 3A, 3B, and 3C are diagrams that represent the functional components of embodiments of an automotive module, a fieldbus module, and a

10   translator, respectively, of the microprocessor of Figure 2.

[10]   Figure 4 is a flow chart illustrating an exemplary process for communicating messages between an automotive module and a fieldbus module illustrated in Figures 2 and 3.

[11]   Figure 5 is a flow chart illustrating in more detail exemplary logic for

15   processing a message within the common language format illustrated in Figure 4.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[12]   With reference to Figure 1, an embodiment of a self-contained, on-board, CAN-to-fieldbus converter ("converter") 10 for communicating non-automotive,

20   industrial automation devices or components ("industrial devices") 11 on a fieldbus network 12 (any of a number of industrial network protocols available) .. . and automotive computers or devices ("automotive devices") 13 on a control area network ("CAN") 14 is shown. The converter 10 includes a CAN-capable

microprocessor 15, a vehicle network transceiver 16, and a combination

industrial network transceiver 18 and protocol handler 19. The transceiver 16

may be connected to the microprocessor 15 via a serial bus 17 and the protocol

handler 19 may be connected to the microprocessor 15 via a parallel bus 20.

5   Each of these components will be described in turn below.

Industrial devices

[13]   In regard to the industrial devices 11, exemplary industrial devices 11

include, but not by way of limitation, an entire electrically powered air

conditioning system including: refrigerant compressor pump, fans, blowers,

10   valves, and sensors; air compressors; hydraulic pumps; vacuum pumps; electric

motors; audio systems; video systems; and various temperature, pressure, and

position sensors.

Fieldbus network

[14]   The fieldbus network 12 is defined to be any data communications

15   network specified by hardware and software protocols with formats native to the

industrial device that are different from the protocols that specify the automotive

control area network. Exemplary fieldbus networks 12 include, but not by way of

limitation, Mod bus, Profy bus, RS-45, Device Net, and various proprietary buses

or networks. A fieldbus network 12 may also include another automotive

20   network as defined by various SAE standards.

Automotive Devices

[15]   In regard to the automotive devices 13, exemplary automotive devices 13

include, but not by way of limitation, engine, transmission, ABS brake system,

steering system, automotive mechanically powered HVAC system, entry/exit

door systems, remote control multiplex systems, power take off systems, trailer

monitoring systems, interior and exterior lighting systems, sign display systems,

and dash board display systems.

5   Vehicle network transceiver

[16]   The vehicle network transceiver 16 may connect into or on an electronic

data bus network that satisfies the network hardware and/or software protocols

(interface specifications) and can send and receive the electronic signals that

represent messages.

10   Industrial network transceiver

[17]   The industrial network transceiver 18 serves a similar function to the

vehicle network transceiver 16, but for the industrial network.

Protocol handler

[18]   The protocol handler 19 is the logical processing of standard message

15   identification, source, destination, and synchronization formats to extract the

specific content of the message.

CAN-capable microprocessor

[19]   An exemplary CAN-capable microprocessor 15 includes a computer circuit

board with a data network interface that satisfies the hardware and software

20   protocols of SAE standard J-1939. With reference to Figure 2, the

microprocessor 15 may include an automotive module 30, a translator engine 40,

and a fieldbus module 50. A database 60 may be coupled to the microprocessor

15 and include language tables, translation tables or rules, and other data. The

language tables, translation tables or rules, and/or other data may be added to the database 60 during manufacture or may later be transferred to the database 60 from the fieldbus network 12 and/or the CAN 14.

[20] With reference to Figure 3A, the automotive module 30 may include a receiver 70 that receives incoming messages from the transceiver 16 and a transmitter 80 for transmitting messages to the transceiver 16. The automotive module 30 communicates with the translator engine 40 in a manner to be described below. The automotive module 30 is the hardware/software interface to the automotive CAN 14 that satisfies the hardware protocol specification. It may or may not incorporate any of the message protocol format coding and decoding.

[21] With reference to Figure 3B, the fieldbus module 50 may include a receiver 90 that receives incoming messages from the transceiver 18/protocol handler 19 and a transmitter 100 for transmitting messages to the transceiver 18/protocol handler 19. The fieldbus module 50 communicates with the translator engine 40. Similar to the automotive module 30, the fieldbus module 50 is the hardware/software interface to the fieldbus network 12 that satisfies the hardware protocol specification. It may or may not incorporate any of the message protocol format coding and decoding.

[22] With reference to Figure 3C, the translator engine 40 may include an auto (CAN bus)-to-common language module 110, a fieldbus-to-common language module 120, a common language to auto (CAN bus) module 130, and a common language to fieldbus module 140 for translating incoming messages to a correct

format for further processing or for delivery to the automotive devices 13 or

industrial devices 11. These can be implemented, for example, but not by way of

limitation, with logical algorithms or lookup tables.

[23]   An exemplary method for communicating between the automotive devices

5   13 on the control area network (CAN) 14 and the industrial devices 11 on the

fieldbus network 12 using the converter 10 will now be described. Messages

from the automotive devices 13 are received by the transceiver 16 via the CAN

14. The transceiver 16 converts the signals from the automotive signaling

voltages of the messages to microprocessor-compatible levels. The messages

10   are sent via a serial bus 17 to the microprocessor 15 for interpretation of these

messages. As will be described in more detail below with respect to Figures 4

and 5, depending on the content of the message, it is either discarded or

processed and sent via a parallel bus 20 to the industrial protocol handler 19 for

interpretation. After interpreting the data, the protocol handler 19 transmits the

15   data via an integrated transceiver 18 to the industrial devices 11. The protocol

handler 19 properly formats the message according to the requirements of the

fieldbus standard specification. The logic of the protocol handler 19 may be

implemented by a microprocessor software module, but for many standard

networks this is performed in a separate integrated circuit. Whether its

20   implemented in the software of the microprocessor or a separate device, a

unique protocol handler may be provided for each different fieldbus.

[24]   For messages going in the opposite direction, namely, from the industrial

devices 11 to the automotive devices 13, the protocol handler 19 strips off the

extra and/or redundant message formatting information to extract the basic message for transmission to the fieldbus-to-common language translator.

[25]   By separating the protocol handler 19 from the microprocessor 15, any number of different networks 12 can be supported merely by replacing the

5   protocol handler 19 with a protocol handler 19 specific to the networks 12.

[26]   Power consumption of the protocol handler 19 is high compared to the other elements. Accordingly, the converter 10 may include a microprocessor-controlled power supply 21 for the protocol handler 19. When the microprocessor 15 decides that the protocol 19 is not needed (e.g., when the

10   vehicle key is off), the microprocessor 15 may turn the protocol handler 19 off by toggling a control line 22 to a power supply 21. When the output of the power supply 21 is turned off, power no longer flows via power supply line 23 to the protocol handler 19. Depending on the microprocessor 15, information on the parallel data bus 20 may also be interrupted at this time.

15   [27]   The self-contained, on-board, CAN-to-fieldbus converter 10 may be contained inside a waterproof enclosure and impervious to the heat and vibration inherent in the automotive environment. Connectors from the converter 10 to electrical elements outside of the enclosure are preferably waterproof.

[28]   With reference to Figures 4 and 5, the microprocessor 15 may be

20   programmed with software that interprets data and passes information between the automotive module 30 and the fieldbus module 50. An exemplary method 145 of communicating messages between the automotive module 30 and the fieldbus module 50 will now be described.

[29]   At step 150, automotive messages are received in the automotive CAN

format by the automotive receiver 70 of the automotive module 30. At step 160,

the automotive messages are translated into messages of a common format with

the auto-to-common module 110 of the translator engine 40. During this step,

5   the automotive messages are passed through and translated using a table of the

database 60.

[30]   Similarly, fieldbus messages are received by the fieldbus receiver 90 of

the fieldbus module 50 and are translated into messages of a common format

with the fieldbus-to-common module 120 of the translator engine 40 using a

10   different table of the database 60.

[31]   At step or process 170, messages between the automotive module 30 and

the fieldbus module 50 are processed according to one or more rules in the

database 60.

[32]   With reference to Figure 5, the process 170 for processing messages

15   between the automotive module 30 and the fieldbus module 50 will be described

in more detail. The one or more rules in the database 60 contain instructions on

which messages to send or retransmit, which messages to discard, and which

messages to modify (e.g., scale, consolidate). At step 180, common language

input messages are received for processing. The one or more rules in the

20   database 60 determine at step 190 whether to send or discard the messages. If

the one or more rules determine the messages are not relevant, control is

passed on to step 200, where the messages are discarded. If the one or more

rules determine to send the messages on for possible modification, the

messages are passed on to step 210, where it is determined whether to modify

or send the messages. If the one or more rules determine the messages should

be sent on, control is passed to step 220, where the messages are delivered to

the appropriate module 130, 140. If the one or more rules determine the

5   messages should be modified, control is passed on to step 230 where the

messages may be modified one or more times. After modification of the

messages one or more times, control is passed on to step 220, where the

messages are delivered to the appropriate module 130, 140.

[33]   With reference back to Figure 4, at step 240, the common language

10   messages are translated into the destination language message. If the

messages are destined for the industrial devices 11, the common-to-fieldbus

module 140 translates the messages into messages of a fieldbus format. During

this step, the common language messages are passed through and translated

using a table of the database 60.

15   [34]   Similarly, messages destined for the automotive devices 13 are translated

with the common-to-auto module 130 to an automotive format using a different

table of the database 60.

[35]   At step 250, messages in the fieldbus format are delivered to the fieldbus

module 50, and the transmitter 100 of the fieldbus module 50 delivers the

20   fieldbus message to the transceiver 18. From there, the fieldbus message is

delivered to the industrial devices 11 through the fieldbus network 12.

[36]   Messages of the automotive format are delivered to the automotive

module 30, and the transmitter 80 of the automotive module 30 delivers the

automotive message to the transceiver 16. From there, the automotive message is delivered to the automotive devices 13 through the CAN 14.

[37]   The self-contained, on-board, CAN-to-fieldbus converter 10 and method shown in the drawings and described in detail herein disclose arrangements of

5   elements of particular construction and configuration for illustrating a preferred embodiment of structure and method of operation of the present invention. It is to be understood, however, that elements of different construction and configuration and other arrangements thereof, other that those illustrated and described may be employed for providing a self-contained, on-board, CAN-to-

10   fieldbus converter 10 in accordance with the spirit of this invention, and such changes, alterations and modifications as would occur to those skilled in the art are considered to be within the scope of this invention as broadly defined in the appended claims.